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Urban transport in Latin America

Some considerations on its equity and efficiency

*Ian Thomson**

The travelling conditions of all the city-dwellers of Latin America are made more difficult by high levels of congestion, but the lower-income strata are in a particularly negative position, since they are usually limited to the use of buses and thus have to spend a larger proportion of their time and money on travelling than the better-off sectors of the population.

There are three main forms of public transport in the region: buses, suburban railways, and the metro or underground railway. Generally speaking, the first of these is the most frequently used form of transport, although it is usually also the least favoured by public policies, for whereas both suburban railways and the metro are normally subsidized by the State, buses receive subsidies only in exceptional cases, and sometimes these amount to less than bus operators pay out in taxes and other charges. Consequently, in order to improve the travelling conditions of the lower-income strata it would be necessary to give more favourable treatment to bus transport.

In this respect, the author suggests that one essential measure would be to reduce the congestion caused by private cars and taxis in order to expedite the passage of buses, which could be achieved through a system of tolls or extra charges. In this way, better use would be made of the existing infrastructure by transferring road space to those means of transport which use it most sparingly, thus reducing the pressure for expansion of the physical capacity of the urban transport system (either through the construction of metros or of new roads for surface transport), improving the level of service offered by buses, and perhaps also making it possible to reduce fares.

*Staff member of the CEPAL Transport and Communications Division.

I

The relation between family income and accessibility

1. *The urban layout and income*

There can be no doubt that the problems associated with urbanization represent one of the biggest challenges faced at present by Latin America. It should be borne in mind that for the most part, urbanization is a relatively recent phenomenon in the region. Thus, in 1963 two United States researches wrote that the study of urbanization in Latin America was at that time a relatively new subject because the development of any really large centre of urban population was also quite recent.[1] Due largely to the fact that in this region the cities reached maturity at a different time from those of the industrialized countries, they display different characteristics whose consequences are not always properly appreciated.

For the present study, one of the most important differences between many cities of Latin America and others in the North is due to the spatial distribution of the social classes within them. It is a well-known fact that the inner areas of the cities of the North are frequently inhabited by members of the less privileged social classes, often immigrants who have just arrived and are living in seriously depressed environmental and economic conditions. Among the best-known examples of this are Harlem in New York and Brixton in London. It is also a fact that the higher-income families of the cities of the North often move to the outer suburbs, where the environmental conditions are more attractive to them.

These tendencies are not of course unknown in the cities of Latin America, but here they are much less marked that in the North. The situation varies from one city to another, but in some cases at least there does not appear to be any correlation in Latin America between the average family income in different areas of

[1] W. Stanley Rycroft and Myrtle M. Clemmer, *A Study of Urbanization in Latin America*, Commission on Ecumenical Mission and Relations, The United Presbyterian Church in the USA, 1963.

the city and the location of those areas within it, or any tendency for the higher-income areas to be nearer the centre of the city.[2] The reasons for this difference between the cities of Latin America and those of the North vary from one case to another: among them are such facts as the inadequate public transport systems of many Latin American cities, which make long daily journeys to and from work unattractive; the frequently adopted Latin American solution of transferring low-income city dwellers from relatively central shanty towns to houses and apartments which are more permanent but also further away from the centre of the cities; and the different cultural features of Latin Americans and dwellers in Northern countries as regards their requirements for recreational goods and services.

Figure 1 considers the case of the area studied in the analysis of the viability of the São Paulo metro. The data refer to a sample of 20%[3] of the approximately 190 traffic zones into which the region studied was divided, and they indicate that it is possible that there may be some tendency on the part of higher-income inhabitants to live closer to the city centre. The correlation analysis carried out for the whole 190 zones does not give any statistically conclusive result, but it was observed that the highest-income area was 4.3 kilometres from the centre, whereas the lowest-income area was 14.5 kilometres away. It can certainly be safely concluded that in São Paulo there is no perceptible tendency on the part of higher-income citizens to live further away from the centre.

Table 1 refers to the metropolitan region of Buenos Aires. The first column shows the average family income by which the traffic zones were classified, while the second column shows the average index of 'accessibility' of the respective groups or zones or, to be more exact, it gives a measurement of the facilities existing for travelling from home to the areas of the city where there are more factors of attraction, such as those areas where jobs are concentrated. It is demonstrated that there is a tendency for the zones of lowest income to have the worst accessibility. This does not necessarily imply that the lower-income groups live further away from the centre of the city, although this is also probably true, but it does imply that the lower-income groups generally have to travel more in order to reach their destination, that is to say, their places of employment or recreation.

Obviously, the tasks of the urban transport system are influenced by the spatial distribution of the lower-income classes. The poor of the Latin American cities often have to travel long distances in order to reach the areas which offer the most attractive employment opportunities. Moreover, they frequently live in relatively isolated areas of low or medium population density which will probably be provided with few public transport services if this is left entirely to the market forces, and for which it may not be economically viable to provide mass transport systems.

Table 1

RELATIONSHIP BETWEEN FAMILY INCOME, ACCESSIBILITY AND JOURNEY GENERATION RATES FOR THE METROPOLITAN REGION OF BUENOS AIRES, 1970

Average family income of zone, in pesos per month	Index of accessibility	Number of journeys generated per family per day
Up to 600	4.44	4.45
600- 800	8.97	5.09
800-1 000	8.99	5.13
1 000-1 300	17.78	7.47
1 300 or more	21.80	9.21

Source: Prepared on the basis of *Estudio preliminar del transporte de la región metropolitana*, vol. I, Ministry of Public Works and Services, Buenos Aires, 1972.

2. *Journey generation and travel times, by income groups*

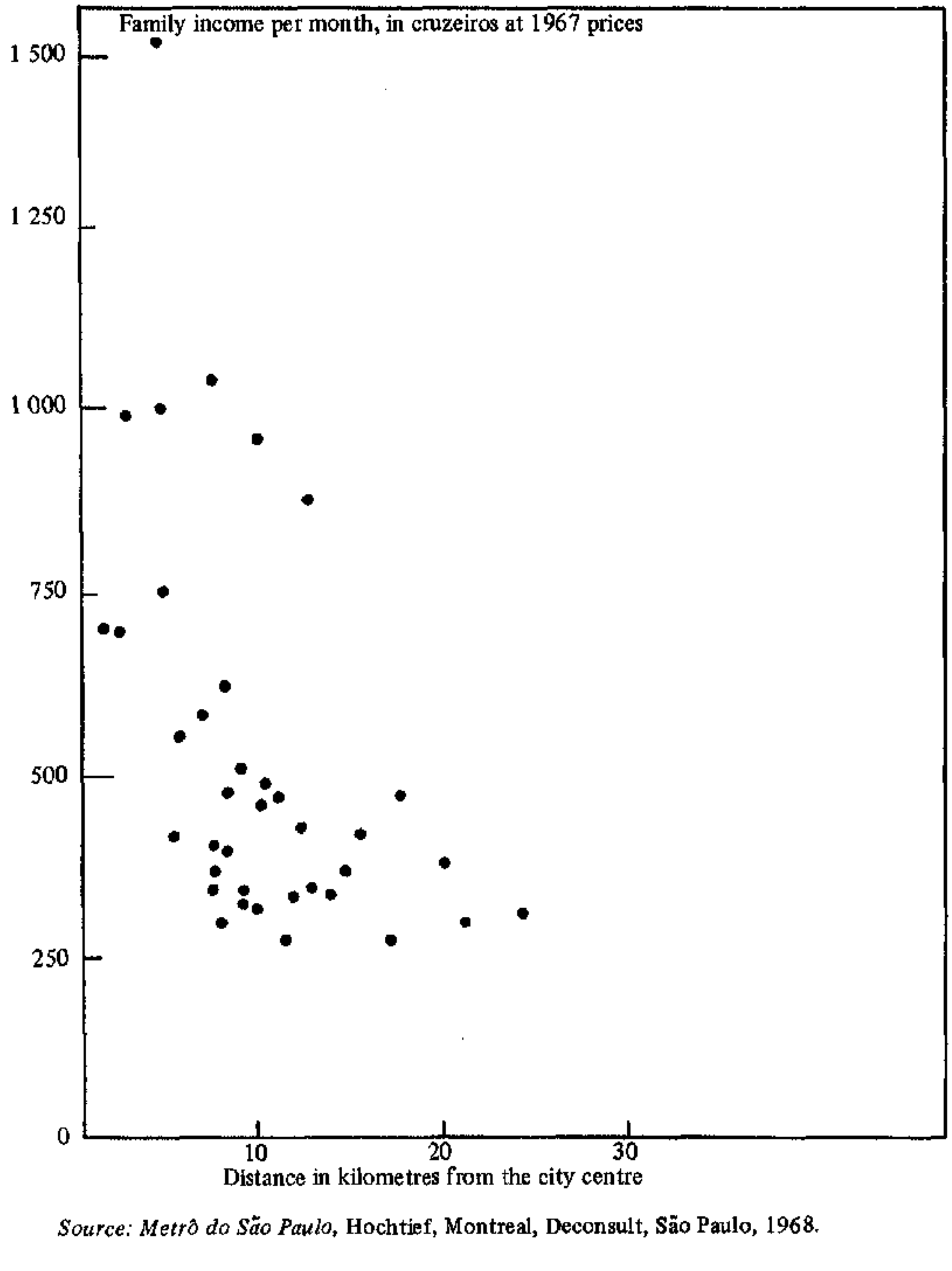
Lower-income families generally make fewer journeys per day than higher-income families,

[2] An extreme example is that of Brasilia, where the richest persons live in the "Plano Piloto", while the poorest ones live in the satellite towns.

[3] The sample was made by selecting every fifth zone in a numerically ordered list.

Figure 1

RELATIONSHIP BETWEEN FAMILY INCOME AND DISTANCE FROM CITY CENTRE: SÃO PAULO, 1966



Source: Metrô do São Paulo, Hochtief, Montreal, Deconsult, São Paulo, 1968.

both because of the importance of the travel cost itself for them and because of the expenditure they would make when they reach their destination. This tendency of lower-income families to make fewer journeys is aggravated when they live in the most inaccessible areas, where travel costs and times are relatively large. Moreover, there are very few lower-income families, of course, which own private cars, and this deprives them of another important stimulus for making journeys, which is the mere fact that a car is available.

Figure 2 shows the combined effects of these influences in the case of São Paulo. 'Essential' family travel (for work and education) increases in proportion to income up to the middle and upper-middle levels, but subsequently varies little with rising income, since it is improbable that further increases in income would be accompanied by the employment of a larger number of family members or the attendance of more children at school. The total journey generation continues increasing with income at all the levels covered by the figure, however, since the better-off families make more journeys for recreational or social purposes or in order to attend to personal matters.

Table 2 concerns the case of Salvador (Bahía, Brazil). The number of jorneys per family increases in a constant manner in line with income, and the same occurs with the number of members of the family travelling (together with the proportion of family members travelling) and the number of journeys per person.

Table 2

BRAZIL: DAILY TRAVEL CHARACTERISTICS IN SALVADOR (BAHIA, BRAZIL)

(Averages for all sizes of families)

Family income per month, in cruzeiros at 1975 prices	Less than 417	417-834	835-1 251	1 252-2 085	2 086-3 336	3 337-4 587	4 588-5 838	5 839-8 340	8 341-12 510	Over 12 510
Travellers per household	1.4	1.8	2.2	2.7	2.9	3.1	3.2	3.2	3.5	3.8
Journeys per person	2.9	3.0	3.0	3.3	3.6	3.6	4.0	4.3	4.6	4.9
Journeys per household	4.1	5.4	6.6	8.9	10.4	11.2	12.8	13.8	16.1	18.6
Average speed of travel, door to door (km/h)	10.8	12.0	12.0	12.0	13.2	13.2	13.8	12.6	14.4	15.0
Travel time per traveller (minutes per day)	103.1	108.2	108.0	111.1	116.7	114.8	116.9	125.0	124.4	121.0
Travel distance per traveller (km/day)	18.2	21.9	21.8	22.6	25.1	25.4	27.2	26.0	30.0	30.1
Travel distance per household (km/day)	25.5	39.4	48.0	61.0	72.8	78.7	87.0	83.2	105.0	114.4
Number of persons in family	4.45	5.22	5.58	5.99	6.12	6.18	6.32	5.51	6.21	6.48

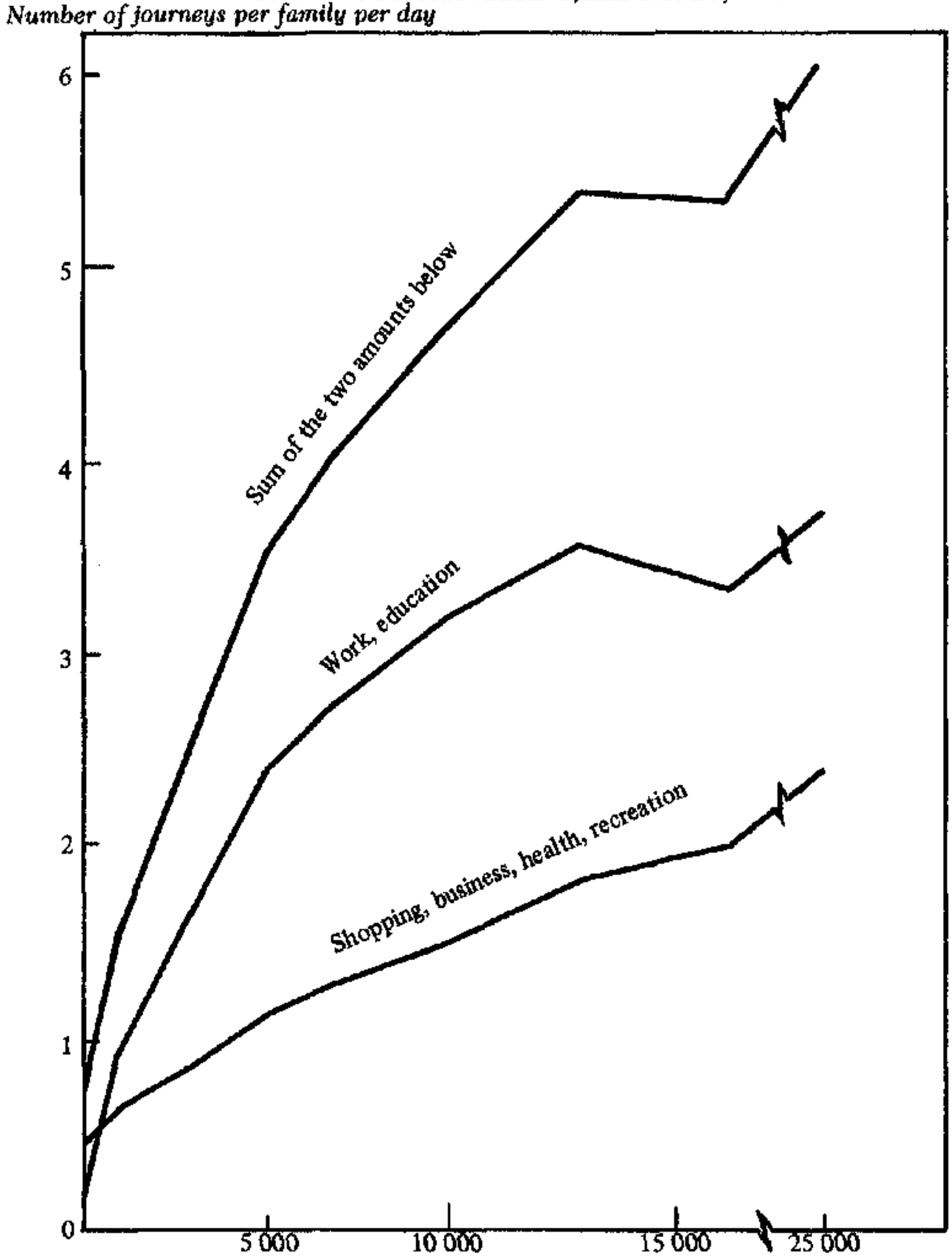
Source: World Bank, Economic Development Institute, Infrastructure Division.

These indicators show that poorer persons do not take advantage of the installations and services offered by the city to the same extent as better-off persons. Table 2 also shows that lower-income families cover a shorter distance than better-off families, although the distance covered per traveller continues to be relatively constant.[4] On average, travellers of the bottom two income brackets cover 20 kilometres per day, whereas travellers in the top two income

[4]The fact that the distance covered per traveller remains constant despite changes in income may be due to the rather unusual layout of Salvador. Poorer persons tend

Figure 2

RELATIONSHIP BETWEEN NUMBER OF JOURNEYS AND FAMILY INCOME, BY REASONS FOR TRAVELLING, SÃO PAULO, 1977



Source: Metropolitan Urban Transport Company of São Paulo.

to make do with travelling shorter distances, because although they would perhaps prefer to travel further in order to live in a more attractive area, this is out of the question for them because of the extra cost and the longer travelling time involved.

brackets cover a distance which is 50% greater. The case of Salvador reveals that door-to-door travel speed rises from about 11 km per hour in the case of the bottom income groups to about 15 km per hour in the case of the richest groups of the 10 groups considered. This range of speed is not particularly great, and the result is that higher-income families spend a somewhat larger total daily travelling time per traveller than members of lower-income families. From what we have seen elsewhere, this feature of the situation in Salvador is not typical of other cities in Latin America, and it is considered to derive from the rather special layout of the city, since many higher-income families live in the hills surrounding the valley where the rest of the city is located. These hills are connected with the city centre by roads with a great many curves on which it is not possible to travel very fast.[5]

The information available for other cities clearly indicates that it is more normal for the total travel time per traveller to be inversely proportional to income. Table 3 shows the data for Bogotá, and table 4 those for Santiago, Chile. The same conclusion is compatible with the data in figure 3 on the case of São Paulo, where the higher-income families make a larger proportion of their journeys in relatively short travel times, compared with poorer families.

It seems reasonable to assert, in general terms, that lower-income families not only make fewer journeys than higher-income families, but also spend considerably more time on each journey. It would appear that each traveller in these families spends a higher proportion of his time travelling, even though he makes fewer journeys.

3. *Transport costs in relation to family income*

According to family expenditure surveys carried out in various Latin American countries during the last 15 years, the proportion of the expenditure of lower-income families spent on urban public transport was not particularly great, and was generally less than 5% of total expenditure.

Table 5 shows some interesting conclusions of these studies. Today, however, the travel needs of a considerable proportion of low-income families mean that they must devote considerably greater percentages of their total expenditure to transport. Let us take,

Table 3

BOGOTA, COLOMBIA: RELATIONSHIP BETWEEN AVERAGE DAILY TRAVEL TIME PER TRAVELLER AND FAMILY INCOME

Monthly income, in pesos at 1972 prices	Daily travel time (minutes)
Up to 500	127
500- 1 000	117
1 000- 1 500	112
1 500- 2 000	113
2 000- 3 000	105
3 000- 5 000	107
5 000-15 000	102
15 000-30 000	98
30 000 or more	83

Source: A. Roth and Y. Zahavi, "Travel Time Budget in Developing Countries" (article to appear shortly in *Transportation Research, op. cit*).

Table 4

SANTIAGO, CHILE: RELATIONSHIP BETWEEN TRAVEL TIME PER TRAVELLER AND FAMILY INCOME

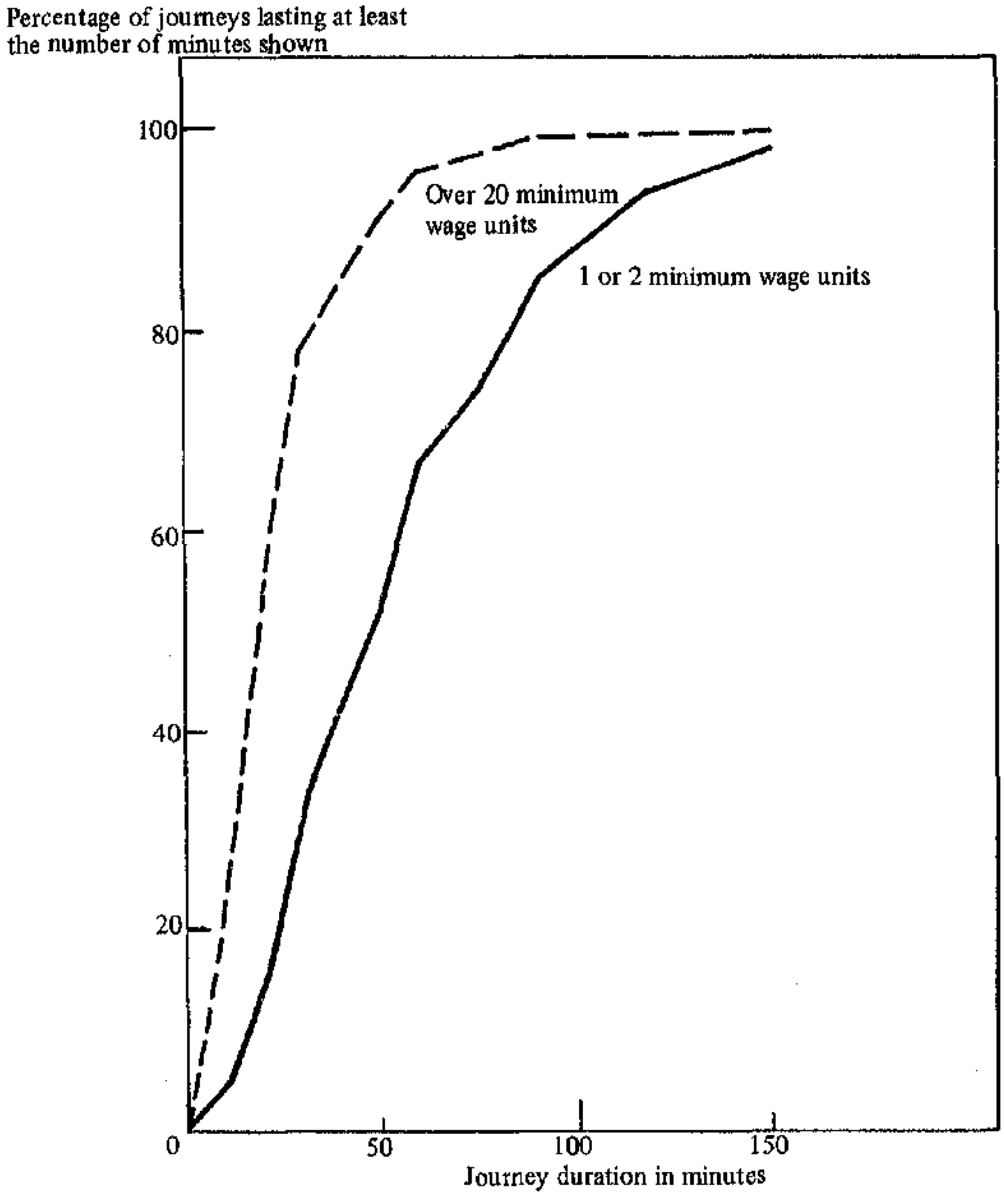
Monthly income, in pesos at 1977 prices	Daily travel time (minutes)
Up to 1 000	91
1 000- 2 500	88
2 500- 5 000	84
5 000-10 000	79
10 000-15 000	74
15 000-20 000	68
20 000 or more	67

Source: Catholic University, Chile, through World Bank (quoted in "Travel Time Budget in Developing Countries", *op. cit.*).

[5]See "Travel Time Budget in Developing Countries" by G. Roth and Y. Zahavi, shortly to appear in the magazine *Transportation Research*, Pergamon Press, Oxford, England.

Figure 3

TRAVEL WITHIN THE METROPOLITAN AREA OF SÃO PAULO, BY DURATION OF JOURNEY, FOR FAMILIES WITH INCOMES OF ONE OR TWO MINIMUM WAGE UNITS AND OVER 20 MINIMUM WAGE UNITS (1977)



Source: Data supplied by the Metropolitan Urban Transport Company of São Paulo.

for example, the hypothetical case of a low-income family of Santiago, Chile, earning approximately 7 000 pesos. If all the members of the family[6] make four journeys per day, then the total monthly expenditure on urban travel would be of the order of 13% of family income.

Table 6 shows that a Brazilian worker earning a minimun wage is obliged, depending on the city where he lives, to spend between 10% and 20% of his very modest income in order to make a minimal number of journeys on public transport (50 journeys per month), the great majority of them between the places where he lives and works. The table also seems to show that the fare he has to pay does not depend so much on the size of the city (and hence on the length of the journey) as on the attitude of the authorities to public transport. In Rio de Janeiro, where the municipally-owned buses do not form a substantial part of the fleet and where (until very recently) a very fragmented form of entrepreneurial organization was tolerated, the fare is 60% higher than in São Paulo, where the opposite situation obtains and the Municipal Passenger Transport Company runs substantial deficits. The fare in São Paulo costs only a little more than in Bõa Vista, the capital of the recently established State of Roraima, which has a population only 1% that of São Paulo. In Curitiba, which is perhaps the most progressive town in the whole of Latin America from the point of view of urban transport, the fare is relatively low in spite of the substantial size of the city and the high level of service offered by the bus system.

If the family expenditure surveys correctly reflect the travel costs of lower-income families in the biggest cities of Latin America under present conditions, then the members of these families must have to cover on foot distances which they would normally be expected to travel by using motor transport. It is indeed a fact that the members of low-income families cover long distances on foot in order to avoid

[6] It may be noted from table 2 that lower-income families in Salvador make 4.06 journeys per day.

Table 5

OFFICIAL ESTIMATES OF PROPORTION OF TOTAL SPENDING OF LOW- AND HIGH-INCOME HOUSEHOLDS DEVOTED TO URBAN PUBLIC TRANSPORT IN SELECTED CITIES OF LATIN AMERICA

City	Year	Type of transport	Percentage of total spending	
			Low-income households	High-income households
Buenos Aires	1969/70	Public transport	2.76	1.83
Rio de Janeiro	1961/62	Urban collective transport	4.7	3.7
São Paulo	1961/62	Urban collective transport	4.4	3.6
Rio de Janeiro	1967	Urban collective transport	3.98	1.14
Recife	1967	Urban collective transport	1.8	1.3
Porto Alegre	1967	Urban collective transport	3.2	1.0
Bogotá	1967	Public transport	2.75	1.60
Medellín	1967	Public transport	2.23	1.63
Cali	1967	Public transport	2.49	1.50
Quito	1967/68	Public transport	0.01	0.01
Guayaquil	1967/68	Public transport	0.00	0.01
Lima	1968	Public transport	2.64	1.87
Caracas	1966	Public transport	4.73	1.45
Maracaibo	1967	Public transport	4.70	1.00

Source: Estadísticas sobre la estructura del gasto de consumo de los hogares según finalidad del gasto, por grupos de ingreso, Cuadernos Estadísticos de la CEPAL, No. 4, CEPAL, 1978, on the basis of data provided by the countries.

paying bus fares, as became clear in interviews with these persons carried out by the press. The quantitative significance of these journeys on foot is perhaps not sufficiently taken into account in some surveys, because the latter concentrate on journeys by motor transport.

Table 6

COST OF URBAN BUS FARES IN THE STATE CAPITAL CITIES OF BRAZIL, AS A PERCENTAGE OF THE MINIMUM WAGE

City	Cost of fare in US$ (equivalent)[a]	Percentage of minimun wage represented by 50 bus journeys per month
Aracajú	0.13	9.7
Belém	0.18	12.6
Belo Horizonte	0.24	14.2
Boa Vista	0.20	14.0
Brasilia	0.34	20.1
Campo Grande	0.22	15.4
Cuiabá	0.23	16.1
Curitiba	0.175	10.3
Florianópolis	0.16	9.5
Fortaleza	0.17	12.7
Goiânia	0.15	10.5
João Pessoa	0.15	11.2
Macapá	0.20	14.0
Maceió	0.13	9.7
Manaus	0.16	11.2
Natal	0.18	13.4
Porto Alegre	0.22	13.0
Porto Velho	0.20	14.0
Recife	0.18	12.6
Rio Branco	0.15	10.5
Rio de Janeiro	0.35	20.7
Salvador	0.21	14.7
São Luis	0.17	12.7
São Paulo	0.22	13.0
Teresina	0.18	13.4
Vitória	0.22	13.0

Source: Statistical Report of the Inter-Syndical Department of Statistics and Socioeconomic Studies, São Paulo.
[a]The data correspond to September 1981 and an exchange rate of Cr$ 100 per US dollar was used.

The incidents which take place when public transport fares are raised in the cities of Latin America provide significant proof of the incidence of fares in family expenditure. The citizenry is frequently opposed to these rises, and its opposition often involves violence. An extreme example which speaks for itself is described in a news item in the *Jornal do Brasil* of 21 August 1981, the first paragraph of which reads: "Over 750 buses damaged (over 50% of the city fleet), according to the Bus Operators' Association; other buses burnt; electricity poles chopped down; shots fired by the military police; at least 31 people hurt, and total confusion in the centre of Salvador (Bahía, Brazil): such was the result of the demonstration provoked yesterday afternoon by the League Against Rising Prices in protest against the 61% increase in public transport fares". If the latter figure seems somewhat excessive, it should be compared with the prevailing rate of inflation, which was around 100% in Brazil in 1981, and it should also be borne in mind that this was the first fare increase for a number of months.[7]

4. *Conclusions on the relation between family income and accessibility*[8] *in Latin American cities*

Travelling conditions are very disagreable for all income groups in many Latin American cities. The proportion of families who own cars is much smaller in most Latin American cities than in the cities to the North, but the traffic congestion is probably worse. It is not so much the number of automobiles as the way they are used that determines the seriousness of congestion, and in Latin America the use of automobiles, particularly at peak traffic hours, is encouraged by the absence of restrictions which could be applied to govern this use. The congestion is made worse by the driving habits, as drivers are less responsible socially and have

[7]See "A insatisfação popular preocupa", in *Transporte Moderno*, September 1981, Editora TM Ltda., São Paulo. This article suggests that Brazilian urban bus companies may have placed less emphasis on the traditional fight for greater profitability in order to concentrate their efforts on preserving their bus fleets against the popular fury fomented by the substantial role played by bus fares in the family budget.

[8]Accessibility may be defined as "ease of reaching desirable attractions". In more technical terms, the accessibility of a zone i of a city may be defined as $\sum_{j=i}^{n} A_j C_{ij}$,

a greater propensity to impede the flow of traffic by parking in the streets, which are in any case frequently relatively narrow. Although no results are given for Latin American cities, a soundly based study on urban travelling conditions concluded that the mean travelling speeds at peak hour in the city centres of Calcutta, Lagos and Manila were much lower than those in London, Paris and New York.[9] An example of the travelling conditions in Latin American cities is provided by the fact that at peak hour in the Avenida Presidente Vargas, the main artery of Rio de Janeiro, buses travel at only 3.5 km per hour.[10]

In comparison with higher-income families, there are fewer travellers in the lower-income families or urban areas of Latin America and they make fewer journeys, but each of these involves more time. In most cases, it is probable that the total daily travelling time per traveller goes down as income rises, even though the number of journeys made increases with income.

Lower-income families are frequently affected by unemployment, and include school-age children who do not regularly attend school. They may therefore have to make relatively fewer journeys to work and school. Above the income level at which it might be expected that the normal number of family members would be employed and receiving education, the number of journeys made per day for the 'essential' purposes of work and education does not vary perceptibly as a function of income. The rate of generation of journeys for other purposes, however, continues to increase slowly with income, which implies that the better-off the family, the more it tends to take advantage of the services offered by the city. While journeys to work do not increase significantly as income rises once a certain level has been reached, it may be assumed that the difficulties presented by travelling encourage workers to take jobs in the light of the transport conditions and not merely the attractions of the jobs themselves.[11]

II

Effects of urban transport policy in Latin America on different income groups

1. *Those benefiting from urban transport subsidies*

The predominant means of urban transport in Latin America is the bus. In the great majority of cities it accounts for all movements of urban passengers who use public transport (not including collective taxis, which are of importance in some cities). Even in cities with substantial rail systems, of which there are only four in South America (Buenos Aires, Rio de Janeiro, Santiago (Chile) and São Paulo), the bus predominates.[12] In Buenos Aires, for

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where A_j is an index of the attraction of the zone j; C_{ij} is a measure of the cost of transport between i and j, recognizing both the money component and other cost components (such as travel time); and there is a total of n zones, ordered i, ... j ... n. There are also other formal definitions, but the above gives an idea of the concepts involved.

[9] J. Michael Tompson, "Great cities and their traffic", in *The Economist*, 11 August 1979.

[10] *O metrô do Rio de Janeiro e o futuro sistema integrado de transporte de massa*, Rio de Janeiro Metro Company, October 1976, p. 18.

[11] A newspaper item entitled "Worker wants nearby job" which appeared in the *Jornal do Brasil* of 28 June 1981 gives us details of a specific case: "Dona Escolástica dos Santos, a 60 year old nurse, went to an agency looking for a job as children's nurse, companion or something of the sort. She went to see about a job in the Barra de Tijuca sector of Rio de Janeiro but did not take it because although the wages of over 10 000 cruzeiros were good, the bus fares were very expensive. This is not a unique case. In employment agencies the supply of lower-paid labour has fallen off considerably for jobs in the centre and southern areas of the city".

[12] The Santiago subway system, or metro, is not strictly

example, in 1970 over half the journeys were made in buses, a little over 15% in automobiles and less than 15% in the metropolitan railway system, including the underground railways and the ordinary railways.[13] In Rio de Janeiro in 1970, the buses transported 1 427 million passengers, compared with 196 million passengers transported by the city railway and 425 million corresponding to taxis and private cars together.[14] In 1981 it is estimated that in Greater Rio de Janeiro the buses transported more than seven times as many passengers as the suburban trains, the ferryboats and the metro together.[15]

In some cities of Latin America there are bus services belonging to the public sector, but where these exist they generally complement those run by private entrepreneurs. In many cities, including such capitals as Brasilia, Buenos Aires, La Paz and Santiago, there are no publicly-owned bus services, and even in cities where they do exist they are frequently basically commercial lines which seek to cover their costs and, if possible, make a profit, although sometimes (but not always) they provide services which for various reasons are not attractive to private sector entrepreneurs.

It is not frequent for direct operating subsidies to be given to private bus owners, but indirect subsidies are common in the form of lower rates of taxation (on turnover, fuel and import duties), financial assistance for renewing the fleet faster than would be the case if purely commercial considerations were taken into account, etc. The relative importance of these indirect subsidies has not been analysed, but at all events bus operation can still produce a positive net yield for government bodies, even when the assistance in the form of tax reductions is taken into account. In the case of Caracas, for example, it was calculated in 1970 that the taxes and other charges paid by bus owners (3.4 million bolívares or approximately US$ 1.7 million at 1980 prices) exceeded the costs corresponding to buses in respect of the road services provided, which came to 2.9 million bolívares.[16] Furthermore, in Buenos Aires in 1970, the bus owners contributed 0.115 pesos per kilometre travelled in the form of taxes, whereas the estimated costs of the traffic police and the maintenance, amortization and interest costs of the infrastructure came to 0.031 pesos per kilometre.[17]

In some cases, as already stated, however, the bus transport system does receive subsidies. Even if it does receive them, however, there are sometimes interventions in the bus services on the part of the authorities (or permitted by them) which do not necessarily benefit users. In net terms, it is difficult to say whether users pay less, or whether they receive better services than if there were no subsidies or other forms of intervention. Thus, in São Paulo the Municipal Passenger Transport Company operates at a loss, which could be considered equivalent to a subsidy, but on the other hand the newspaper *Jornal do Brasil*, in its edition of 30 August 1981, reports that "taxes and social charges represent almost half the cost of fares (of urban buses in Brasil)". It is quite possible that users would prefer to have neither subsidies nor taxes. In Bogotá, subsidies are granted to buses that maintain regular services, but the institutional and entrepreneurial system for this form of transport in the city is so intricate that only a very thorough investigation could determine the net effects of all the forms of intervention, one of which is the granting of subsidies.[18]

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speaking a railway system, as it does not actually use rails for the running of the trains (except in the sidings and in case of emergency), since the carriages have rubber tires which run on a concrete track. For reasons of convenience, however, it will be considered in this article as a railway.

[13] *Estudio preliminar del transporte de la región metropolitana*, vol. 1, Ministry of Works and Public Services, Buenos Aires, 1972. Furthermore, in terms of passenger/kilometres, the buses achieved figures twice those of the railways of that city (see vol. 2 of the same study).

[14] *O metrô do Rio de Janeiro e o futuro sistema integrado de transporte de massa, op. cit.*

[15] *Jornal do Brasil*, 28 June 1981.

[16] *Cargas impositivas a los usuarios de la vialidad del área metropolitana de Caracas*, Venezuelan Government/World Bank/Alan M. Voorhees and Assocs. Inc., Caracas, 1973.

[17] *Estudio preliminar del transporte de la región metropolitana, op. cit.*, volume 2.

[18] See Alcaldía Mayor de Bogotá, D.E., Depto. Administrativo de Tránsito y Transportes, *Racionalización del transporte público de pasajeros en Bogotá D.E.*, Plan Piloto I.

In most Brazilian cities, no direct subsidies are given in respect of the operation of bus services, and this more or less reflects the policies applied in other parts of the region. The effects which this principle of not granting subsidies has on income distribution are aptly summed up in the following section of an article published in the *Jornal do Brasil* of 19 August 1979, reporting on an urban transport congress held in Porto Alegre:

"It was stated at the congress that the users of collective transport are concentrated in the income strata receiving between one and eight minimum wage units. These passengers provide 80% of the revenue received by the buses in the country and they are the persons most affected by the prevailing system, because their low income obliges them to live further away from their workplaces than those who earn more.[19] This means that the less the traveller earns, the more he has to spend on transport.[20] Correcting this situation would involve the establisment of a fare system which does not take into account the number of kilometres travelled so much as the income of the passenger".

The tone of the article from which this passage is taken indicates that although from the official point of view there does not appear to be any intention at all of seeking to change the predominantly private ownership of collective transport in the country, the semi-official discussions held at the congress reveal some degree of sympathy for public ownership and for the fixing of fares in line with social criteria. There was undoubtedly genuine interest behind this sympathy, but any change of policy should take into account the studies made on this matter recently in some countries of the North, which suggest that: (i) subsidies can bring with them a certain degree of inefficiency which prevents the whole benefit of the subsidy from reaching the users of the services provided; and (ii) private operation may be more efficient than public operation.[21]

It may be noted that in Brazil there is increasing support for the adoption of a single fare for the whole urban area, regardless of the distance travelled by the user.[22] This criterion has been applied for a long time in some cities, such as Curitiba and São Paulo, but it is now receiving more official support because of the concern with the high incidence of fares in the budgets of lower-income families, who frequently have to cover long distances using public transport. An additional incentive in favour of its adoption is the threat of social violence mentioned earlier, which actually broke out in Salvador in August 1981. Another very attractive idea which has been discussed but not yet put into practice is that of a "transport voucher", which would take the form of a ticket valid for a journey on public transport, issued by employers to their lower-paid staff. The issue of these vouchers by employers would be encouraged through fiscal incentives such as credits which would reduce the amount payable in income tax.[23] The generalized application of this criterion to cover also the unemployed and school children would provide very considerable advantages from the point of view of social justice in Latin American urban transport.

Although Latin American urban bus operation apparently does not usually receive substantial subsidies, urban rail transport does receive them in considerable amounts, as in other parts of the world. There are two types of urban rail transport in the region: the metros or underground railways, and the urban/subur-

[19]Note that this coincides with a provisional conclusion reached in section 2 below.

[20]The article exaggerates somewhat on this point: those who earn more can travel more, and it is possible that they also pay more to do so, using private cars, taxis, collective taxis or luxury buses with air conditioning.

[21]See reports LR 952, *The Economics of Stage Carriage Operation by Private Bus and Coach Companies*, and SR 541, *Subsidisation of Urban Public Transport*, published by the Transport and Road Research Laboratory of the United Kingdom, and Alan Walters and Charles Feibel, *Ownership and Efficiency in Urban Buses*, World Bank, Washington.

[22]See "Eliseu (Resende, the Minister of Transport) insists on the flat-rate fare" in *Jornal do Brasil*, 11 July 1981.

[23]See "This year the Government will bring in transport vouchers to compensate wages" in *Jornal do Brasil*, 31 May 1981. In actual fact, these vouchers were not introduced in 1981, possibly because of concern over reduction of revenue from income tax.

ban railways, which we shall call here suburban railways. The construction of the suburban railways which exist in the region came to an end in the 1930s (although there have lately been some signs of reactivation) while the construction of metros began in the 1960s, except in the case of Buenos Aires, where the first section was inaugurated in 1913 (in Buenos Aires this type of transport is called "subte"; the word "metro" is used in the other countries).

The suburban railways are of importance in only four cities: Buenos Aires, Rio de Janeiro, São Paulo and Mexico City. Suburban railway services also exist, although they are less important, in a few other cities which include Recife and Salvador in Brazil, Veracruz in Mexico and Valparaíso in Chile. With the financial participation of the World Bank, a new suburban electric railway is being built in Porto Alegre, indicating a renewal of interest in Brazil in this form of transport. Such railways are also being built in some other cities.

There can be no doubt whatever that the three main suburban railway systems in South America run at a big loss, although separate accounts are rarely published for such systems, which are considered essentially as social services by the national rail companies (although part of the suburban rail system in São Paulo is run by the railway enterprise of the State of São Paulo, FEPASA). It may be noted that action has been initiated to transfer these services to autonomous bodies which would only be responsible for metropolitan passenger transport. In one specific case, that of Rio de Janeiro, it has been demonstrated that users of the suburban trains pay less than half the operating costs of their journeys.[24]

The users of suburban railways in the region generally belong to the low and middle-income groups, so that the policy of subsidizing the operation of such rail services could have favourable consequences from the point of view of income distribution. In the case of Rio de Janeiro, the immediate beneficiaries of the subsidies are the lower-income groups living in the northern part of the city, while in the case of Buenos Aires most of the beneficiaries are the middle-income inhabitants of Lomas de Zamora, Quilmes, Morón, 3 de Febrero, General Sarmiento, San Isidro and Vicente López. As for São Paulo, there are quantitative indicators which show that the users of the suburban rail services come from the lower-income groups, as is clear from table 7.

Table 7

FAMILY INCOME INDICATORS OF USERS OF VARIOUS FORMS OF TRANSPORT IN SAO PAULO, BRAZIL

Form of transport	Approximate monthly family income, in cruzeiros at 1977 prices[a]
Bus only	7 750
Private car only	14 000
Taxi only	12 750
Metro only	12 500
Other rail transport only	5 500
Bus/Bus[b]	7 000
Bus/metro[b]	8 750
Bus/other rail transport[b]	7 000

Source: Data provided by the Metropolitan Urban Transport Company of São Paulo.

[a]Round figures are given for income because the available sources of information did not permit more precise calculations to be made.

[b]Journeys involving the use of both the forms of transport referred to.

Probably because of the loss-making nature of the services offered and the considerable differences between the suburban rail services and the rest of the activities of national and State railway companies, it is evident that in South America such suburban systems have suffered from a lack of sufficient investment in the past. Thus, for example, only a relatively small part of the Buenos Aires system is electrified, while in Rio de Janeiro and São Paulo serious incidents have taken place in which the passengers have destroyed whole trains when the service has suffered longer than normal in-

[24]See the article "Train fares are going up" in *Jornal do Brasil*, 30 May 1981.

terruptions. There are some grounds for hoping, however, that the situation of the passengers of the suburban railways in the region may improve in the future. In Buenos Aires, for example, the heavily-used lines serving General Roca are being electrified, and in Rio de Janeiro 150 new trains have recently been acquired. Investments are also being made to improve the quality of suburban rail transport in Belo Horizonte, Porto Alegre, Recife, Salvador and other cities of Brazil.

As already noted, at present metros are operating in five Latin American cities, namely: Buenos Aires, Rio de Janeiro, Santiago (Chile), São Paulo and Mexico City, while the Caracas metro is to be opened in 1983. Except in the case of Buenos Aires, all these systems began to operate in the last 20 years. No metro system in Latin America covers its total expenditure entirely with its operational revenue, and indeed none of them even covers its operating costs, without including the civil engineering investment costs. In some cases, such as that of São Paulo, there is an operating deficit (it was sometimes anticipated, howe ;er, during the stage of evaluation of the projects, that the income would cover the social costs). The case of Santiago (Chile) may be used as an illustration. In 1979, when the metro fare in that city was 5 pesos, the operating costs, including the interest and depreciation on the rolling stock, were around 15 pesos, and the fare would have had to be raised to 30 pesos in order to cover also the capital costs of the construction. Generally speaking, these fares are fixed in the light of urban bus fares, the desirability of gaining a reasonable share of the urban travel market, and the objective of using the available capacity of the systems. The metros of Latin America must therefore be considered as a highly subsidized form of transport.[25]

It seem appropriate to ask who benefits from the subsidies given to the metros in the region. The users frequently do not come from the lower-income families. Table 7 shows that in 1977 the average family income of persons using the São Paulo metro for the whole of their journey (who are probably the users gaining most from the system, since the metro serves them directly and they do not need to make transfers at either end of the journey) was equal to that of taxi users and only slightly below that of persons travelling by private car. In Rio de Janeiro, the first section of the metro line built with top priority provides transport between the districts of Flamengo and Botafogo in the southern area, inhabited by families in a good economic position, and the centre of the city, while the other part of the line provides transport between the district of Tijuca, also inhabited by middle-income families, and the centre, although it is true that other sections of the basic systems cover the needs of lower-income travellers.[26] The recent extension of the first metro line in Santiago (Chile) to the heart of the high-income section of the city benefits high-income passengers, although the western half of the same line and the second line of the metro provide services for other users with lower incomes. Generally speaking, the Buenos Aires metro serves the inner part of the city within the ring formed by the main stations of the interurban railway system, so that it probably benefits above all the middle and high-income families whose members work in the city centre.[27]

[25]See *Algunos aspectos de la justificación socioeconómica de los ferrocarriles metropolitanos en América del Sur* (E/CEPAL/R.264), where a comparison is made of what the consultants expected from the metros of South America during the evaluation stage and the actual results recorded once they were being constructed or had already been built.

[26]Moreover, the projected extension of the priority line will take the Rio de Janeiro metro to areas inhabited by high-income families, such as Leblon and Copacabana.

[27]In the case of Buenos Aires, it is not easy to find data to prove this statement, although experience does seem to point to this: in this case, only very indirect estimates can be made. In the case of the São Paulo metro, the information contained in a study carried out in 1977 by the Metropolitan Urban Transport Company makes it possible to calculate approximately the average income in different types of occupations, and with other data from the same source it is possible to break down employment, by type of occupations, in different parts of the urban area. It is therefore possible in this case to calculate that workers in the traditional centre of the city earn an average of 4.15 minimum wage units, compared with the 4.02 minimum wage units corresponding to the urban area as a whole. In reality, however, the wage advantage of those working in the city centre is probably greater, since for a given occupation, those working in the centre earn more than those in any other part of the city.

The lack of detailed statistical information for the cities in which there are metros means that it is impossible to form a precise idea of the income of those using the metro systems of the region, although for the most part they probably come from the upper and middle deciles of the income distribution scale. Metros are only viable in the case of extremely dense traffic flows concentrated in a narrow corridor, and it is therefore generally impossible to justify their construction when they only involve radial lines between densely populated non-peripheral districts and the city centre, in order thus to serve the needs of persons travelling every day between their homes and their workplaces.[28] Since those who work in city centres probably come from the middle and upper segments of the income scale, the predominance of such persons among users of the system may in practice be an inherent characteristic of metros.

Moreover, those who benefit most from metros may not be those who actually use them. Metros are only one of the various policy measures which can be put into practice in order to solve transport problems on the main radial roads of cities. The various options open include the following: reserving lanes for the exclusive use of buses; issuing supplementary licences for automobiles to be used in congested areas; and prohibiting automobiles from entering the main arteries and city centres when traffic density is at its highest. All these options call for much smaller capital investment than metros, but all of them in turn cause some kind of inconvenience to private car users, because they transfer road space from automobiles to buses and possibly other forms of public transport. If a metro is constructed instead of adopting one of the other much cheaper options, this implicitly means that private car users are being benefited, since they would be prejudiced if any other option were selected. Thus, by transferring part of the surface traffic demand from the roads running parallel to the metro, this solution tends directly to favour those who use private cars.[29]

In addition, from a logical point of view it could be argued that most of the benefits of metros are ultimately received by the owners of real estate near the metro, for these persons can raise rents in areas close to metro stations, on the grounds of smaller travelling time and costs, thus appropriating for themselves the benefit initially received by upper-income travellers. There have been some technical discussions in Latin America on the possibility of financing metro construction through differential property taxes on real estate close to metro stations, whose value obviously increases with the construction of this type of transport, but unfortunately these discussions have not had any practical effects.[30]

2. *The efficiency of conventional systems of running urban transport*

The irrational use of urban transport systems, which is frequent in Latin America (and in many other parts of the world), results in total transport costs which are higher than necessary, including avoidable costs for fuel and personal travelling time, and has unfavourable consequences on real income distribution, since those who use private vehicles impose extraordinary costs on those who use public transport. This irrational use is mainly the result of the unsuitable price fixing mechanisms applied to urban transport, which do not permit the optimum utilization which could be achieved if the road space were rationed by market mechanisms, modified in the light of social considerations.

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[28] This is because of their high cost, which is between US$ 30 and 100 million per kilometre.

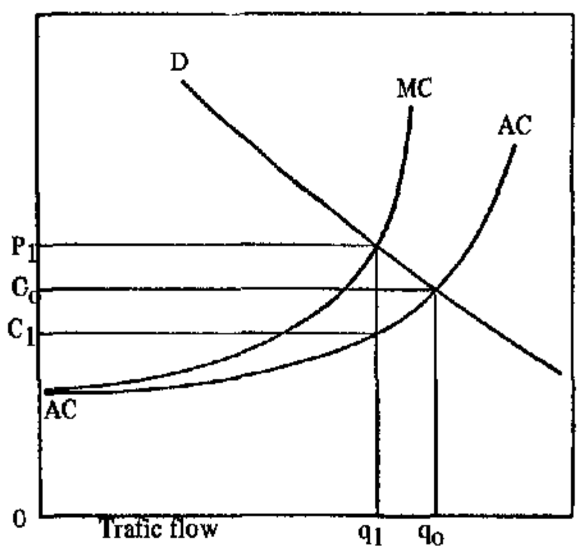
[29] The road space freed during peak traffic periods by the diversion of demand to underground transport is generally quickly used by surface traffic, which moves from other times and other routes in order to take advantage of it, thus practically cancelling out any potential benefit which could otherwise result. In other words, the corresponding demand is very elastic.

[30] The distributional effects of the subsidy financing have not been investigated in detail in the present study, but there are indications that in Canada transport users in general are in a better economic situation than those whose taxes finance the transport subsidies. See Mark Frankena, "Income distribution and transit subsidies", in *Journal of Transport Economics and Policy*, London School of Economics, September 1973. The tax systems of Latin America are generally relatively regressive, and it is probable that the conclusions reached regarding Canada are even more true of Latin America.

This situation is set forth in figure 4, which represents an urban road or set of roads. The curve AC shows the relation between the traffic volume (per period of time) and the cost per vehicle. This cost, which could be called the private cost, since it directly affects all automobiles,[31] increases slightly with traffic flow up to moderate levels of flow, above which it intensifies more sharply. The curve D shows the number of automobiles wishing to travel, as a function of the cost that each must pay. Equilibrium is reached with a flow of q_0 when each automobile pays a cost of c_0.

Figure 4

GENERALIZED RELATIONSHIP BETWEEN TRAFFIC FLOW, MEAN COST (PRIVATE) AND MARGINAL SOCIAL COSTS



Source: Prepared by the author.

[31]Owners and drivers of automobiles must pay these costs by definition, although perhaps they do not fully appreciate their real magnitude because of their faulty perception of costs (since it is very difficult to find out the real fuel consumption per kilometre covered at different speeds and to determine the maintenance costs per kilometre). In addition, there are taxes and subsidies which mean that the market prices are different from the real economic costs.

It should be noted that the entry of a new automobile into the traffic flow causes an increase in the private costs of the other road users; only at very low traffic volumes is it possible to bring in an additional vehicle without appreciably reducing the speed of the rest of the traffic. It is possible to draw another curve, which we shall call MC, which indicates the change in the total cost caused by each addition to the traffic flow, as a function of that flow. This change comprises the private costs of the additional vehicle and the marginal social cost, that is to say, the extraordinary costs imposed on the automobiles already existing in the traffic flow as a result of the reduction of speed and other negative effects. The curve MC lies above the curve AC (or at the same level when the traffic flow is very low) and becomes much steeper at higher flow levels. If each road user were obliged to pay not only his private costs but also the marginal social costs caused by him, the equilibrium point would be at a flow of q_1 when the cost of each unit in the flow would be c_1. Each of the units would have to pay a sum equivalent to $(p_1 - c_1)$ in the form of a toll or special license in order to establish this optimum situation.[32]

Establishing a practical system for collecting such tolls is difficult from both the technical and social point of view, although probably not impossible. One version of a simplified option has been applied in Singapore and is analysed in chapter III of the present paper, and a similar system has been worked out but not put into practice in Caracas and London. The idea has been seriously considered in Brazil and is still under study in Chile. Much of the effort spent on traffic organization all over the world may be interpreted as an attempt to reduce traffic levels from a point characterized by q_0 to levels characterized by q_1, by using parking regulations or physical restrictions of some other kind.

What is the magnitude of these marginal social costs? Figure 5 shows the relation between the private costs and marginal social

[32]It can be demonstrated that this movement towards the new and optimum equilibrium point generates benefits equal to $q_1 (C_0 - C_1) - 1/2 (P_1 - C_0) (q_0 - q_1)$.

costs and the traffic flow for some roads in Caracas, and demonstrates how the marginal social costs increase as the theoretical capacity of the road installations is approached. Table 8 shows the marginal social costs in Caracas by district and type of road for the morning peak hour.[33] In parts of the city centre, every kilometre covered by an automobile at the morning peak hour imposes a cost of over 50 US cents on the other road users. In the case of the little-used roads of the outer districts, however, the marginal social cost is practically nil.

So far, we have been talking about the cost per vehicle. It is common practice in traffic engineering circles to express other vehicles also in passenger car units (pcu), i.e., the number of automobiles which have the same effects on the traffic flow as the type of vehicle under consideration. The pcu equivalent of a bus varies depending on the particular case under consideration. Some authorities in Latin America use a pcu factor of 2 for a bus in general calculations, but using a factor of 3 would not represent any underestimation of their disturbing effect on the public transport traffic flow. Using this pessimistic factor for buses, however, and an occupation factor of 60, which is typical for maximum transport conditions in Latin America, then a marginal social cost of x cents per automobile-kilometre becomes a marginal social cost of 0.05x cents per bus passenger. If the average automobile transports 1.5 persons, then the cost per occupant of the automobile would be 0.60x cents i.e., 13 times the cost per bus user. Other collective transport media, such as collective taxis and minibuses, cost society more per passenger than an ordinary bus, but less than an automobile.

The difference between the private costs of urban travel by automobile in Latin America and the total costs, including those imposed on other members of society, is often heightened by the fact that automobile travellers use socially valuable parking space for which they pay little or nothing.[34] The following paragraph taken from the *Jornal do Brasil* of Rio de Janeiro of 15 October 1978 illustrates a general phenomenon through a particular case:

"These street parking spaces reserved for official use (in this case for the United States Consulate) are often used by adventurous car owners who risk going into the centre by automobile. The persons who help to park and look after automobiles (an occupation unknown in the cities of North America) encourage car drivers to continue doing this and always find some way of locating a space for them somewhere among the spaces which are not being used at that moment by official cars, charging between 5 and 10 cruzeiros for their services".

In Santiago and other cities it frequently happens that those engaged in the work of parking and looking after vehicles reserve kerbside spaces for their regular customers and recieve monthly or weekly payment for this. The marginal social costs of parking vehicles in the street varies appreciably depending on the particular local circumstances, the cost per automobile being less, for example, when there is a continuous line of cars parked along the kerb and more when there is only one. In favourable circumstances,[35] the cost per working day could be 50 cents, while in unfavourable circumstances it could be much more.[36]

Some car drivers park their vehicles in private areas and pay market prices for doing

[33] It should be understood that the figures given in this table show orders of magnitude. They depend to a very critical extent on the particular form of the equations for the traffic flow with respect to the traffic speed in each case. It should be borne in mind that the congestion in Caracas is of a special nature and is generally very serious even compared with other Latin American cities.

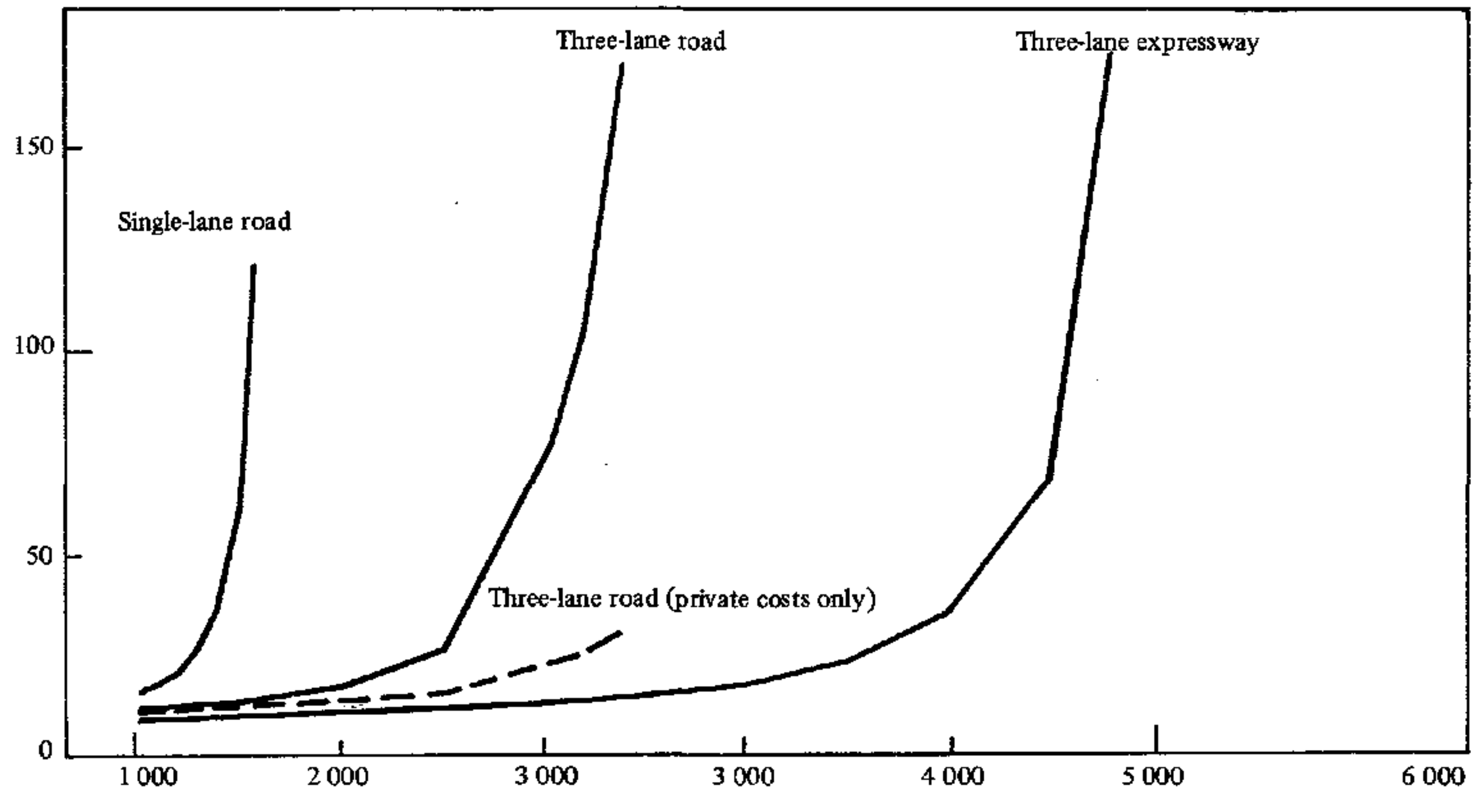
[34] It may be noted that figure 4 refers to a journey from a given place of residence to a parking place in the centre of the city, rather than to a specific street or set of streets. The curve AC would represent the private costs borne by the driver, including any payment made in connexion with parking. The curve MC would include the cost of the space occupied while parked: costs which are borne by society in general and not by the traveller in particular.

[35] That is to say, if the automobiles are parked at the rate of 180 per kilometre at the edge of a one-way two-lane road for 8 hours, when the traffic flow per hour is a constant 500 pcu (passanger car units).

[36] The situation is more acute when drivers queue up in the street while they are waiting for someone. Mothers of high-income families frequently wait en masse in their cars for their children to come out of school, giving rise to serious traffic problems. An article in the *Jornal do Brasil* of 15 March 1981 entitled "Double parking outside schools plays havoc with traffic" speaks for itself.

Figure 5

PRIVATE COSTS AND MARGINAL SOCIAL COSTS AS A FUNCTION OF TRAFFIC FLOW FOR DIFFERENT TYPES OF ROAD UNDER THE CONDITIONS PREVAILING IN CARACAS, IN U.S. CENTS AT 1980 PRICES



Source: Interpreted from *Cargas impositivas a los usuarios de la viabilidad del área metropolitana de Caracas,* Venezuelan Government/ World Bank/Alan M. Voorhees and Associates, Caracas, 1973.

Table 8

MARGINAL SOCIAL COSTS PER KILOMETRE PER VEHICLE AT MORNING PEAK HOUR FOR VARIOUS DISTRICTS OF THE CARACAS METROPOLITAN AREA IN 1971, BY TYPE OF ROAD, IN U.S. CENTS AT OCTOBER 1980 PRICES

City district	Type of road							
	One lane	Two lanes	Three lanes	Expressway				Average for all types of road
				Two lanes	Two and a half lanes	Three lanes	Four lanes	
CBD	54.5	73.2	34.0	34.6	20.2	43.7	-	45.6
Manicomio/23 de enero	12.4	36.6	14.7	4.4	-	-	-	11.5
Vista Alegre/La Vega	0.0	6.6	12.5	7.5	4.4	4.4	-	5.5
Antimano	-	19.8	-	-	-	-	-	19.8
Las Acasias/Cementerio	3.8	11.3	16.0	7.7	-	10.0	25.5	16.0
El Valle and southward	-	0.0	13.3	4.4	-	4.4	-	8.4
Cotiza/El Bosque	8.5	6.5	12.6	6.3	-	12.0	-	9.1
Los Chorros/El Marqués	0.0	1.5	7.0	-	14.0	4.4	-	5.7
Baruta and environs	0.0	0.6	-	-	6.0	-	-	2.6
La Calefornia/El Hatillo	0.0	0.0	-	-	-	-	-	0.0
Petare and beyond	5.4	-	-	-	-	-	-	5.4
Country Club/ Los Palos Grandes	0.5	8.3	8.1	10.5	30.5	4.4	-	10.4
Las Mercedes/San Román	-	6.2	-	53.5	21.3	-	-	22.7
Chacaito/Santa Mónica	-	6.1	-	-	7.7	-	-	7.1
Pro Patria and beyond	4.3	-	-	6.6	-	-	-	5.3
Average for all types of road	7.4	14.1	16.3	12.9	13.6	8.3	25.5	12.7

Source: Table II.4 of *Cargas impositivas, op. cit.*, adjusted for the effects of inflation and converted into U.S. cents.

so; others part their cars at the roadside and do not pay anything or else only pay a small amount of money to someone who helps to park and look after the vehicles. It is not easy to estimate the social cost of the space occupied, and at all events this varies from one case to another. Assuming that the marginal value of land is the same for different uses, then each car parked in this way for 8 hours near, but not within, the city centre could cost approximately two dollars.

A person who works in the city centre and travels 15 kilometres by car between his home and his workplace at peak traffic times, morning and evening (and does not go home to lunch as many people do in Latin America) runs up a marginal social cost of US$ 2.65 if we use the average cost per kilometre shown in table 7 and assume a social parking cost of 75 cents. This represents a cost of 18 cents per kilometre, although this estimate should be considered only as an illustration.

Owners and users of automobiles in Latin America often have to pay considerable amounts to government bodies in such forms as automobile purchase taxes, import duties and license charges. As these various kinds of taxes do not vary with the number of journeys made, they do not have a direct effect on congestion. The only tax which sometimes assumes significant proportions and which does vary according to the number of journeys made is the fuel tax.

In some countries (Bolivia, Ecuador and Venezuela) gasoline is effectively subsidized: that is to say, the implicit rate of taxation is negative. In other countries, however (Brazil, Paraguay and Uruguay), the taxes on gasoline are relatively high. In Brazil, for example, the gasoline tax works out at about 5 US cents per kilometre for an automobile in urban traffic. If the total marginal social cost comes to 18 cents per kilometre, then these 5 cents could be considered to be a significant contribution to the total. There are some grounds for doubting, however, whether the retail price of gasoline in Brazil, including the tax factor, is much greater than the real economic cost of the product, in view of the fact that the shadow price of foreign exchange in the country is significantly higher than the prevailing official rate. It might be considered that the tax of 5 cents per kilometre matches reasonably well the difference between the real economic cost of gasoline, expressed in cruzeiros, and the retail price less tax. At all events, when considering systems to oblige travellers to pay the marginal social costs which correspond to them, the fixing of an appropriate level of gasoline taxes should be borne in mind.[37]

The argument that urban travelers should be made responsible for the marginal social costs they cause is based on the fact that if no such responsibility exists it cannot be expected that the transport system will function efficiently: in general there will be too many journeys, and a percentage of those made will cost those making them less than their real total cost (for them and for the rest of society). If road users had to cover their marginal social costs, however, there would be significant advantages as regards distribution, including the following:

— the revenue in respect of tolls would be contributed above all by the relatively well-off persons who opted to continue travelling by private car even after the introduction of the road taxation system, and this revenue would be collected by the government to be used for the public good in the manner considered most suitable;

— the transfer of demand from automobiles to buses would increase the frequency and perhaps the density of the bus services, which would be advantageous for existing bus passengers;

— the reduction in automobile traffic would free road space and increase the speed of the buses and the reliability of the bus services;

— the bus fares should go down, since by increasing the utilization of each vehicle the depreciation and capital costs per passenger carried would be reduced.[38]

III

Policy options for increasing the efficiency and equity of urban transport systems

1. *Summary of some of the problems to be solved*

The foregoing sections of the present study set forth some of the problems which affect the efficiency and equity of urban transport systems in Latin America. From the point of view of efficiency, it is necessary to reduce the total cost implied by a given volume of urban transport or else increase the volume of service

[37] It should be noted that if tolls are raised to reflect the marginal social costs, the traffic flows will generally go down to the pre-existing levels, thus lowering the marginal costs. The optimum toll, in equilibrium conditions, would be less than the marginal social costs before applying the tolls, that is to say, in figure 4, the vertical difference between the curve MC and the curve AC at a traffic level q_0 is greater than in the case of a traffic level q_1.

[38] It is not *a priori* obvious that the bus fares would go down, since in spite of the higher speeds these vehicles might not be able to make more journeys during peak traffic times and the extra demand for bus transport caused by the transfers from private cars would increase the traffic concentration at those times. See the appendix to the present article, which describes a model developed in order to analyse this point. According to this, it would appear that the bus fares would indeed go down except in extreme cases.

provided for a given cost. From the point of view of equity and distribution, the main source of concern is that the degree of accessibility of the lower income groups is rather inferior. Going more deeply into this point, the following special objectives could be noted:

(i) Action should be taken to give present or potential travellers greater awareness of the total private and social cost of their travel, so that they only make those journeys whose benefit is greater than their cost, ensuring also that these journeys are made by the most efficient means and at the most suitable time of day.

(ii) The speed of the buses should be increased so as to reduce travelling time, which tends to discourage travel by lower-income families, thus at present reducing their accessibility.

(iii) The level of services provided by the bus system should be improved so as to make necessary fewer transfers in order to complete journeys.

(iv) The monetary cost of public transport should be reduced.

(v) The high capital investment represented by new urban roads and metro systems should be avoided, since these have to be financed with subsidies which frequently tend to benefit the less needy members of urban society.

A sixth objective could also be included, namely, that of avoiding direct subsidies to urban bus companies, since there are certain indications that such subsidies reduce efficiency. Instead, emphasis should be placed on the desirability of keeping bus operation in private hands, since it is probable that the transfer of such services to the public sector results in an increase in operating costs.[39]

2. *An idealistic solution*

If all road users were obliged to absorb the marginal social cost of their journeys, this would represent an important step towards achieving all the objectives listed in the previous paragraph, the first of them being reached by definition.[40] The second objective would be achieved because the resultant reduction in the volume of private vehicle traffic would increase the speed of the buses (although not so much as that of private cars). The third aim would be favoured because the transfer of demand to the bus system would increase the service frequency and promote an increase in the coverage of bus services as well as stimulating greater route density. The fourth goal would be satisfied because the operating costs would be reduced in terms of time.[41] The fifth objective would be achieved because the greater efficiency obtained from the existing surface transport system would reduce the comparative advantages that metro systems might offer and make it less desirable to expand the road system (table 9, which is explained below, provides an example of this). The sixth aim would not be tackled directly, although the system of charging for road use ("road pricing") would stimulate the transfer of resources to private bus transport, thus increasing its profitability and hence reducing any need for subsidies.[42] It would improve the quality of services provided and reduce any pressure in favour of the transfer of such services to the public sector.

However, the practical difficulties standing in the way of the application of a system of charging for road use which would oblige users to absorb exactly their marginal social costs are such that this system probably cannot be introduced in the near future in spite of the considerable benefits it could bring. For the past ten years the necessary technology has existed for: (i) recording the passage of private cars through particular streets in the city road network; (ii)

[39]This possibility is shown in various studies, such as those of Alan Walters and Charles Feibel, *Ownership and Efficiency in Urban Bus Operation*, World Bank, Washington, D.C., and R. Tunbridge and R. Jackson, *The Economics of Stage Carriage Operation by Private Bus and Coach Companies*, Transport and Road Research Laboratory, England.

[40]Although differences might persist between what travelers are really paying and the extent to which they are aware of what they are paying.

[41]There would certainly be a rise in the ratio between the number of buses required and the number of passengers transported, although not sufficiently to offset the drop in operating costs, except in special cases (see annex 1).

[42]Except in extreme cases (see annex 1).

Table 9

COMPARISON BETWEEN THE JOURNEY TIME SAVINGS OBTAINED FOR A GIVEN VOLUME OF URBAN JOURNEYS AT PEAK TRAFFIC TIME BY THE APPLICATION OF A SYSTEM OF SUPPLEMENTARY LICENSES FOR ENTERING THE CITY CENTRE AND THE SAVINGS OBTAINED BY BUILDING A METROPOLITAN RAILWAY SYSTEM, USING AS AN EXAMPLE THE METROPOLITAN AREA OF CARACAS IN THE CONDITIONS PREVAILING IN 1971

(In United States dollars at October 1980 prices)

	Existing situation: no metro and no supplementary licenses	No metro, but with suplementary licenses at an optimum price of US$ 1.25 per vehicle per hour	With metro between Petare and Pro Patria but no supplementary licenses
Number of hours of travelling time for private car users	31 920	27 015	30 005
Number of hours of travelling time for bus users	31 733	33 230	19 375
Number of hours of travelling time for collective taxi users	15 918	14 495	8 612
Number of hours of travelling time for metro users	-	-	10 007
Total number of hours of travelling time	*79 571*	*74 740*	*67 999*
Estimated cost of investment, in US dollars at 1980 prices	0	1 000 000	1 350 000 000
Amount of investment needed to save one hour of travelling time	-	207	116 661

Source: (1) *Cargas impositivas..., op. cit.*, especially tables X.1 (Vol. II), 4.12 (Vol. III) and A.1.5. and A.1.6 (annexes); (2) *Quaterly Economic Review*: Venezuela, The Economist Intelligence Unit, London, third quarter of 1980; (3) *Resumen general de costos: costo totál del proyecto*, C.A. Metro de Caracas, October 1981; (4) Central Bank of Venezuela, *Boletín mensual*, various issues, for cost adjustment factors.

transmitting information on the time of passage, the prevailing traffic intensity and the identity of each vehicle so that a central computer can make the necessary calculations; and (iii) adding up the charges owed by each vehicle for subsequent collection. At present, however, it would appear that there are fewer probabilities than before of applying an exact automatic system of road use charges, mainly because of the combination of the high capital costs involved in the establisment of the system and the uncertainties of a political and social nature which could accompany the introduction of such a system.

At the beginning of the 1970s, a plan for the automatic collection of charges from road users in respect of the marginal social costs connected with their use of congested roads was prepared for the metropolitan area of Caracas, although its application in the short term was not recommended. Its capital cost was estimated at the by no means negligible sum of almost US$ 50 million at present prices.[43] Perhaps it would not be very wise to enter into

[43]Government of Venezuela/World Bank/Alan M. Voorhees, and Associates, *op. cit.*.

a commitment to the investment of such a sum without first of all establishing the acceptability of the criteria used by examining the application of other alternatives calling for less capital expenditure. Doubts have usually been expressed about the political and social viability of this kind of road use charges. It has been suggested that charging for the marginal social costs involved in the use of urban roads would be inflationary but this would only be so if governments permitted it to be inflationary, since there is no reason why a change in economic administration which tends to reduce costs (in this case, those of urban transport) should have inflationary consequences.

The degree of political acceptability of the system of charges would be greater if it were introduced (with suitable modifications in line with the location) simultaneously in all urban areas of the country, in order to avoid protests from persons living in a particular urban area on account of having to pay for something (i.e., the congestion they cause) which persons living in other cities do not have to pay. If the net revenue generated in each city were invested for the benefit of residents, such objections could be refuted, although there would always be the danger that the system would be criticized by political interest groups seeking support from sectors of public opinion which are not perhaps properly informed.

3. *Practical alternatives*

More simple alternative ways of charging to cover the marginal social costs can also be conceived. Generally speaking, however, the simple alternatives are less precise and efficient, because they do not link the charge to the distance travelled along congested roads or the degree of congestion prevailing on a particular road when vehicles are using it. Instead, they involve the collection of a uniform amount depending on the class of vehicle entering a particular congested area (normally the city centre) on the basis of the use of congested road space (and hence of the marginal social costs generated) by an average vehicle of the same type entering the area subject to charges. In Caracas, plans and recommendations were made for the application of a programme of this nature, and the basic features of these plans were actually applied in Singapore, with some variations such as those connected with the design of the collection system.[44]

The plan proposed for Caracas is known as "supplementary licensing", since it would call for the acquisition of an extra daily license for each vehicle included in the plan of entry to the city centre. Expressed in 1980 values, this daily license would have cost US$ 3 per private car in 1971, US$ 10 per collective taxi,[45] and US$ 7.50 per truck, after adjusting the estimated license charges fixed for the beginning of the 1970s by the variation in the price index.[46] As it is very likely that the demand for road space per unit of available space has increased since the beginning of the 1970s, it may be assumed that the present optimum rate of charges would be somewhat higher than these values, so that it would be more reasonable to set it at US$ 5 per private car. In the plan proposed for Caracas, buses were exempted from payment for social reasons and in order to simplify the system, but if they had been included the charge would have been approximately three times that estimated for collective taxis, since a bus uses approximately three times as much road space as a taxi.[47] The charge set for trucks in Caracas was discretionally reduced from the value that would have been fixed if only considerations of efficiency had been taken into account. It was considered that the elasticity of demand for urban road space by trucks would be low in relation to price and that the amounts charged

[44]Singapore has features which favour the introduction of a road taxation system: for example, there is only one city in the country and there is a sufficiently firm and disciplined democratic system capable of taking measures to contribute to long-term development and stability. See *Time* magazine, 25 January 1982.

[45]When this plan was worked out, the collective taxis were regular-sized American cars, but today they are small vans and mini-buses.

[46]The index used was that calculated by the Central Bank of Venezuela for the category "miscellaneous expenses", which includes transport. At the beginning of the 1970s, an individual component was not published for transport.

[47]If buses had been included in the system, this would have significantly increased the revenue, but not the economic benefits. The collective taxis, for their part, should now be paying more than if they were still the size of American cars.

to trucks would therefore simply be converted into greater costs for them (and possibly also give rise to difficulties of a political and social nature), without having any major incidence on congestion.

The special license would have to be displayed in the windshield of the vehicle and the supervision of the system would have been carried out mainly through the inspection of vehicles parked in the central area, but also of those being driven; 76 persons would have been needed for this work. It was estimated that the revenue from the plan would have been approximately 110 million bolívares per year at 1971 prices (nearly US$ 56 million at 1980 prices), while the costs would have been slightly over 10 million bolívares per year. At present values, the expected annual revenue of nearly 100 million bolívares would be equivalent to about US$ 50 million. In round figures, the annual economic and social benefits would have amounted to nearly 16 million bolívares (US$ 8 million at present prices), from which it would be necessary to deduct the annual operating costs of the system, which are slightly over 10 million bolívares. The extraordinary initial cost of installing the system would have come to 2 million bolívares, so that the relation between the costs and benefits of the plan would have been favourable.[48] In reality, the long-term benefits might even have been greater. By making possible greater operating efficiency of the urban transport system it would have reduced the need to make big capital investments to improve its functioning. At present, a metropolitan railway system is being constructed in Caracas, and the cost of the first line in the system, from Propatria to Palo Verde, is estimated at some 7 billion bolívares at 1981 prices,[49] or US$ 1 600 million. If Caracas follows the trend of other Latin American cities which have decided to build metros, the final cost could even exceed this very high sum.[50]

Table 9 gives estimates of the total travelling time for the same number of journeys at peak morning traffic density time in Caracas for three different situations: (i) the present situation, without the metro and without additional licenses; (ii) introduction of the system of additional charges for entering the central area of the city, but without the metro; and (iii) with the metro operating between Propatria and Petare, but without additional licenses. It is estimated that the total number of hours travelled under the present system comes to 80 000 at peak traffic density time; with the system of additional licenses (without the metro), this time would be reduced to 75 000 hours, while with the metro but without the system of additional licenses the total travelling time would be 68 000 hours. The system of additional licenses would cost approximately US$ 1 million, while the section of the metro in question, at 1980 prices, would cost US$ 1 350 million, so that whereas each hour of travelling time saved through the application of the system of additional licenses would cost approximately US$ 200, while each hour saved through construction of the metro would cost over US$ 120 000.

The foregoing is not a strict and exhaustive comparison between the relative advantages of a system of additional licenses and those of another solution involving the building of a metro system. At all events, however, the figures are interesting. There can be no doubt that this comparison does not take into account certain negative and tax features of the metro solution: for example, with this system the number of persons travelling to work in their own cars (the preferred means) would be higher than if a system of additional licenses were applied; the metro would provide employment during its construction stage; it would require a large amount of foreign exchange; it would mean setting up a new and very large public

[48] It should be noted that although the license would only have been required for entering the city centre, the reduction in automobile traffic towards the centre would increase traffic speed in the entire urban area. In Caracas, the speed of automobiles in this area at times of peak traffic density would increase from 29 to 35 km per hour, with the cost of a license for entering the central area rising from 0 to 7.2 bolívares per hour at times of peak traffic density. See *Cargas impositivas, op. cit.*, table A. 1.5.

[49] *Resumen general de costos: costo total del proyecto*, Metro de Caracas C.A., October 1981. It should be noted that the extension from Petare to Palo Verde was not part of the original project.

[50] See *Algunos aspectos de la justificación socioeconómica de los ferrocarriles metropolitanos en América del Sur, op. cit.*

sector enterprise to operate the urban transport system, etc.

At all events, it may be asserted that generally speaking the adoption of a system of obliging urban road users to absorb the social costs they generate would tend to reduce the investment needs for the urban transport system. Table 10 gives another example, once more taken from the case of Caracas.[51] This table indicates that for every level of investment in the urban road system, the charging of an additional license of higher value leads to a reduction of the total costs of the transport system (cost of road construction plus cost of road maintenance plus cost of vehicle operation). In addition, it indicates that the total costs arising as a result of the lower investment and the charging of higher sums for licenses are similar to those resulting from high investment and the charging of medium or small sums for licenses. The main reason why the same total costs (as defined) can be achieved for the urban transport system, regardless of whether investments are higher or lower, is that in the latter case fewer persons would go to work by car, so that the need for road space would diminish.[52]

Table 10

METROPOLITAN AREA OF CARACAS: CONSTRUCTION, MAINTENANCE AND OPERATING COSTS TO USERS ASSOCIATED WITH THREE LEVELS OF ROAD INVESTMENTS (WITHOUT METRO), WITH AND WITHOUT APPLICATION OF A SYSTEM OF SUPPLEMENTARY LICENSES TO ENTER THE CITY CENTRE, 1971-2001

(Millions of bolivares at net 1971 prices)

Level of road investments	Cost of licenses at time of maximum traffic density	Construction costs[a]	Maintenance costs	Operating costs to users[b]	Total costs
	0.00			23 383	25 581
	1.25			23 213	25 411
High	2.50	1 838	360	23 008	25 206
	5.00			23 041	25 239
	7.20			23 515	23 713
	0.00			28 509	30 288
	1.25			24 482	26 261
Medium	2.50	1 434	345	23 624	25 403
	5.00			23 245	25 024
	7.20			23 660	25 439
	0.00			32 506	33 952
	1.25			29 195	30 641
Low	2.50	1 114	332	28 456	29 902
	5.00			23 676	25 122
	7.20			23 833	25 279

Source: Table 6.3 of Technical Supplement to *Cargas impositivas..., op. cit.*
[a]Based on the assumption that no investments will be made after 1980.
[b]Including costs of travellers' time and operation of vehicles for all the hours spent on travelling during the period 1971-2001, assuming that the travel demand will not increase after 1980.

[51]Taken from the report by the Government of Venezuela/World Bank/Alan M. Voorhees and Associates. Chapter 6 of volume III of the report on this study contains a complete technical description of the way in which these figures were obtained.

[52]Note that the amounts referred to in table 10 were not adjusted in accordance with variation in the consumer surplus in the various cases.

4. *Other policy options*

The achievement of the objectives set forth in chapter III.1 of the present paper can also be approached through policy options which do not involve obliging road users to absorb their marginal social costs. Generally speaking, these other options are less efficient, although they may be easier to impose and less conflictive from the social and political point of view. Most of them do not depend on price mechanisms so much as on physical limitations and therefore do not have the result of giving the authorities the benefit of payments made by users of the congested urban road space. When monetary factors are brought in, they generally involve subsidies rather than taxes.

The alternative most frequently used consists of controlling congestion by regulating city centre parking. This alternative may be fairly acceptable in some cases, but it has certain intrinsic drawbacks from the point of view of both efficiency and equity. Frequently its efficiency is reduced because this system is incapable of limiting journeys which go through the centre of the city rather than those which end there. Moreover, reducing the volume of traffic through the central area of the city frees road space in the streets in the centre, and this serves to encourage traffic through the centre.[53] Furthermore —although this is a practical rather than an intrinsic drawback— efforts to stop congestion by establishing a parking policy frequently run into the difficulty that a large proportion of the parking places in the centre of the city are not in the streets but in buildings operated by private or independent authorities, and in many cases these cannot be controlled directly. If the parking policy cannot take these parking places into account, it will probably only be able to solve a small part of the problem.

This impossibility of intervening appropriately in the case of parking places located in buildings (whether those specially constructed for parking or those which combine office and commercial premises with parking areas for employees and clients) also means that control through parking policy has drawbacks from the point of view of distribution, since it is frequently the richest persons who go to work in the city centre and have reserved parking places in such buildings. Through long-term directives on land use it will be possible to expand the control of over parking in buildings, but generally speaking the results of such action take years to show themselves.

In order to achieve significant effects, efforts to improve urban transport systems through direct aid to public transport instead of controls on private cars call for large subsidies. In North America it has been proved that in order to attract a significant number of car users the fares on public transport services would have to be negative,[54] and a similar conclusion will probably be reached in Latin America too. There are some examples of improvement of the quality of service instead of reducing the price of public transport, however, which have succeeded in inducing travellers to stop using their private cars. In 1974, for example, a system of luxury urban buses with air conditioning was introduced in Rio de Janeiro. These buses, known as "Cool Riders", charged higher fares, but neverthless succeeded in attracting some car drivers, without however securing any change in the difficulties of driving to the city centre. Moreover, these buses do not receive direct subsidies.[55] There have not been many attempts to repeat the success of luxury air conditioned buses in other Latin American cities, although this solution undoubtedly deserves greater study with a view to its extension.[56]

[53] A comparison between the effectiveness of a road taxation system and a system of restricting traffic through control of parking is given in the article by J.M. Thomson, "An Evaluation of Two Proposals for Traffic Restraint in Central London", in *Journal of the Royal Statistical Society*, London, 1967, pp. 327-377.

[54] For example, P. Bly, F. Webster and S. Pounds, in their article "Effects of subsidies on urban public transport" in *Transportation*, 9 (1980) note that in most cases the combined cost in terms of time and money of travelling by car is so much less than that of travelling by bus that, even if fares were eliminated completely, it still probably would not be possible to attract most private car users to public transport.

[55] Moreover, when these buses were introduced they did not even have the advantage of reserved bus lanes.

[56] Sometimes this solution is ruled out in practice,

Indeed, recent reports indicate that the Rio de Janeiro "Cool Riders" may be on the point of bankruptcy, caught as they are between the rises in operating costs and the economic problems of the Brazilian middle class, who are their usual clients.[57]

Generally speaking, metros do not succeed either in inducing many of those who have to travel to work to give up using their private car unless at the same time the regulations on car parking are modified, in which case the change of means of transport is due to these modifications and not to the metro. In 1971 it was estimated that the Petare-Propatria metro line in Caracas would reduce the number of private car journeys at times of high traffic density from 129 412 to 124 629, that is to say, by a mere 4%.[58] Another example is that of Santiago, where it was estimated in 1982 that the extension of the metro system from a length of 24.4 km to 82.9 km (including sections of pre-metro) would reduce the number of private car journeys at times of maximum density from 211 682 to 210 849: i.e., a reduction of 0.39%.[59] The claimed improvement in public transport could be justified if additional restrictions were imposed on the use of private cars to go to work, either through making a charge for road use, controlling parking, or using other means so as to offer a satisfactory alternative to those who previously travelled by private car. It should also be borne in mind, however, that perhaps it is not necessary for the public authorities to take special measures in this field: instead, they could simply allow the natural market mechanisms to give rise to services which generate greater demand.

Another policy option which might be considered excessively severe if the real seriousness of the situation were not fully appreciated has been suggested in a previous report of CEPAL[60] and also independently by the Ministry of Transport of Brazil;[61] under this option, private cars would be prohibited from using certain roads and the city centre during peak traffic hours. This alternative could be considered a procedure for reducing the cost of urban transport and improving the travelling conditions of lower-income groups by making those who wish to travel to work by car pay for the road space they use in terms of time and inconvenience rather than money. In economic terms, this alternative is inferior to those obliging road users to absorb their marginal social costs by paying a toll or other similar charge, since the payment would be made in the form of real economic resources rather than through a transfer. If no tolls were paid, the public sector would not obtain revenue. However, this might be better than regulating city centre parking and is worth considering as a viable policy option.

The complete list of options is very long, but few of them go to the real heart of the problem, which is that the relatively well-off drivers of private cars impose costs on the less wealthy who use public transport during times of congestion. It is not pretended that all the problems associated with urban transport in the Latin American region would be solved if a system connected with the concept of charging for the use of congested roads were introduced, or if physical restrictions on the use of private cars were adopted. Even if such measures were introduced, for example, it might continue to be necessary to consider the desirability of giving direct aid to facilitate the travel of the poorest families, but this would take us outside the specific area of urban transport towards the broader field of social policy in general.

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although perhaps not deliberately, when the public authorities fix maximun fares for buses.

[57]See the news item "Cool Riders are causing problems and the operators want to get rid of them", *Jornal do Brasil*, 17 January 1982.

[58]Government of Venezuela/World Bank/Alan M. Vorhees and Associates, *op. cit.*

[59]*Evaluación de alternativas a la red de transporte colectivo independiente de Santiago*, Catholic University of Chile, for the Ministry of Transport and Communications of Chile, 1981.

[60]E/CEPAL/R.264, *op. cit.*, and E/CEPAL/PROY.2/R.9, *An Analysis of Some of the Social Consequences of the Automobile in Latin America*, September 1979.

[61]*Jornal do Brasil*, 3 July 1979.

Appendix

Effects of mechanisms for limiting urban congestion on bus fares

Introduction

It might be queried whether a system of additional urban licenses would really reduce bus fares.

The higher speed permitted by such a measure would tend to reduce the interest costs in respect of the bus fleet and would also help to reduce those operating costs which vary as a function of operating time. Furthermore, the system of licenses would tend to increase the demand for bus services, especially at peak traffic hours, and could encourage the acquisition of more buses, which would only be used during those hours. In addition, systems of additional licenses would only have a favourable effect on the interest costs of the fleet if the higher speed thus made possible enabled the vehicles to complete a larger number of journeys during peak traffic hours, which might not be possible if the bus routes are too long. These repercussions of a system of additional licenses on bus transport are generally not sufficiently recognized. If the negative repercussions outweigh the favourable effects, bus fares might tend to go up rather than down.

In order to study the quantitative importance of the various factors in question, a simple operating model for a bus route was developed. This appendix contains a summary description of this model and of the conclusions derived from it.

Brief summary of the model

The model analyses a bus route for given conditions regarding: (i) the number of passengers to be transported, with the peak traffic hours being distinguished from others; (ii) the speed of the buses at peak traffic hours and outside them; (iii) the characteristics of the bus route and the operating conditions; and (iv) the number of hours of operation, both in total and during peak traffic hours.The supplement to this appendix gives a complete technical description.

The first stage consists of determining the required frequencies, which are calculated separately for periods of peak traffic density and other periods, taking into account the relation between the number of persons needing transport and the capacity of each bus, as well as the minimum frequency which each bus line wishes or is obliged to offer.

Once these frequencies have been established, the number of buses needed is calculated. In order to carry out this calculation for the peak traffic period, the variables used were the service frequency (in the form determined above), the duration of the peak traffic period, and the time taken to cover the whole route. For the period outside peak traffic hours, the frequency and the time needed to complete the route were taken into account.

Estimates were then made of the global operating variables on which costs depend: the total number of kilometres per day covered by the buses on the route; the total operating time; and the total time, including rest periods.

The total costs were calculated by adding together four separate components. The first was the crew costs, which are related to the total time including rest periods. The second was the other time-dependent operating costs (including part of the costs of fuel, depreciation and maintenance) which are based on the total operating time. The third was the interest component, which is a function of the total number of buses needed. Finally the fourth component was the distance-related costs, which depend on the number of kilometres travelled by the buses.

The final result of the calculations is the total cost per passenger transported.

Application of the model

The model took a basic case which was assumed to represent the existing situation and in which the only limitation on private car traffic in the urban area was the parking policy. The test case which was compared with this basic case assumed a situation in which a system of road use charges was applied (or other means of limiting journeys, especially those by private car) at times of traffic congestion.[1] Several variations were made both for the basic case and the test case, in order to see how the result changed according to different circumstances. Table A-2 shows the set of data used in each application of the model, while table A-1, which contains a list of the results of the different applications of the model, presents the corresponding results. The terms used in the model are defined in table A-3.

Summary of conclusions

In most cases it is concluded that the system of charging for additional licenses would reduce the bus costs per passenger, and hence the bus fares. There would only be an increase in fares in cases where (i) the bus routes are relatively short or (ii) the license charge leads to a very appreciable increase in demand for bus services at peak traffic time, with little or no variation in such demand outside those times (especially when the peak traffic period is relatively short).

The longer the peak traffic density period (including the morning and evening peaks) the greater the reduction in fares would be. If this peak period were short, however, the reduction in the round trip time permitted by the charging of additional licenses would not allow the vehicles to return to their terminals with sufficient time to make an extra journey during the peak traffic period.

The changes in fares vary slightly according to the length of the route. If the morning peak traffic period lasts for two hours (and the evening one is of similar duration) and permits a speed of 15 kilometres per hour (without the application of additional licenses) then the application of such licenses would enable fares to be reduced more and more in proportion as the length of route rises from 5 to 15 kilometres (see comparison between application 1 and application 1A). Within this range of distances, the buses can usually carry out more than one journey during the peak traffic time, and the increase in speed made possible by the use of licenses improves the results in this sense. In proportion as the length of the route increases, the application of licenses gradually gives rise to greater effects, as it reduces the relative importance of rest periods at the end of the run.

[1]It should be noted that here it is assumed that buses are exempt from any kind of payment.

Table 1

ESTIMATED VARIATIONS IN BUS COSTS PER PASSENGER TRANSPORTED AS A RESULT OF THE ADOPTION OF A SYSTEM OF CHARGES FOR ROAD USE OR SOME OTHER SYSTEM TO TRANSFER PRIVATE CAR USERS TO COLLECTIVE TRANSPORT, FOR DIFFERENT TYPES OF CONDITIONS

Comparisons between applications shown	Percentage variation in cost when KR is:				
	5	10	15	20	25
1A/1	−5.85	−5.94	−5.97	−5.17	−5.38
2A/2	−1.10	−0.40	−0.88	−1.15	−1.01
3A/3	−4.54	−4.56	−4.57	−4.58	−4.03
4A/4	−0.31	−0.37	−0.07	−0.38	−0.53
2B/2	+0.00	+0.47	−0.39	−0.85	−1.14
2D/2C	+0.04	−0.21	−0.53	−0.70	−0.80

Source: Prepared by the author.

Table 2

ENTRY DATA USED IN THE VARIOUS RUNS OF THE MODEL

Variable	Value assumed for the run indicated										
	1[a]	1A[b]	2[a]	2A[b]	2B[b]	2C[a]	2D[b]	3[a]	3A[b]	4[a]	4A[b]
PPMP	1 000	1 250	1 000	1 250	1 500	1 000	1 250	1 000	1 250	1 000	1 250
PPMFP	150	160	150	150	150	150	150	150	160	150	150
FM					0.1667[c]						
VP	15	17.5	15	17.5	17.5	15	17.5	22.5	25	22.5	25
VFP	19	19.25	19	19	19	19	19	27.5	27.75	27.5	27.5
KR					5[c], 10[c], 15[c], 20[c] y 25[c]						
LBP					0.0833[c]						
LBFP					0.2000[c]						
LCP					0.0333[c]						
LCFP					0.0333[c]						
CB					60[c]						
t_o	7.5	7.5	8	8	8	8.0	8.0	7.5	7.5	8	8
t_1	9.5	9.5	9	9	9	8.5	8.5	9.5	9.5	9	9
CIBA					4 000[c]						
CCH					3.50[c]						
OCOH					2.88[c]						
COK					0.33[c]						
HO					18.50[c]						

Source: Prepared by the author. The source of the monetary values was the report *Cargas impositivas..., op. cit.* These values are expressed in dollars at 1980 prices. They were later revised, however, to make them more representative of Latin American conditions. (It should be noted that since the objective of the model is to estimate the relationship between the cost in a given situation and the cost in another situation, the absolute costs are not very important, although the values must of course be approximately realistic).

[a]Without charges.

[b]With charges.

[c]In all cases.

Table 3

DEFINITION OF TERMS USED IN THE MATHEMATICAL MODEL

Number of persons wishing to enter city centre per hour during period of peak traffic density	PPMP
Number of persons wishing to enter city per hour outside period of peak traffic density	PPMFP
Minimum frequency of service	FM
Speed of service, in km/h, during period of peak traffic density	VP
Speed of service, in km/h, outside period of peak traffic density	VFP
Length of route, km (one way)	KR
Rest time at terminal in outer part of city during hours of peak traffic density	LBP
Ditto, outside period of peak traffic density	LBFP
Rest time at inner-city terminal during hours of peak traffic density	LCP
Ditto, outside period of peak traffic density	LCFP
Load capacity per bus (number of passengers)	CB
Time at which morning peak traffic begins	t_o
Time at which morning peak traffic ends	t_1
Interest costs per bus per year	CIBA
Cost of crew, per hour	CCH
Other operating costs, per hour	OCOH
Operating costs per kilometre	COK
Number of hours of operation per day	HO

When the distances are over 16 or 17 kilometres, however, there is no way that the buses could make more than one complete journey during the peak traffic period, even if the system of additional licenses were introduced, and hence this source of cost reduction ceases to have any effect, although the reduction in fares when the route is 25 kilometres long is nevertheless greater than when it is 20 kilometres, since the effect of the rest periods continues to decline consistently. (It should be borne in mind that generally speaking the licenses would tend to increase the concentration of demand during the peak period and reduce the mean utilization of the buses because of this).

Supplement to appendix: technical description of the model

1.1 The first stage consits of estimating the service frequency. The frequency needed to take care of the traffic flow is calculated separately for the peak traffic period and for the off-peak period, and this frequency is then compared with the specified minimun desired frequency. The frequency selected will be that which offers the best interval sevice. Taking as an example the case of the off-peak frequency, we calculate:

$$\frac{CB}{PPMFP} \qquad (1)$$

and use either this value or that of FM, depending on which of them is smaller. The result is denominated FMFP.[2]

1.2 The number of buses needed can be estimated in more than one way. The model uses different methods for the peak traffic period and the off-peak period. In the first case, we begin by estimating the number of bus journeys (of vehicles, not of passengers) during the peak traffic period through:

$$\frac{t_1 - t_0}{FMP} \qquad (2)$$

[2]The equivalent for the peak traffic period is denominated FMP.

This will give the number of buses needed if no bus is capable of completing more than one round trip during the peak traffic period. The round trip time during this period equals:

$$\frac{KR}{VP} + \frac{2\,KR}{(VP + VFP)} + LBP + LCP \qquad (3)$$

From this we see that at least one bus can make more than one round trip if:

$$(t_1 - t_0) - \left(\frac{KR}{VP} + \frac{2KR}{(VP + VFP)} + LBP + LCP\right) > 0 \qquad (4)$$

If this condition is maintained, then the number of buses needed is:

$$\frac{\left(\frac{KR}{VP} + \frac{2KR}{VP + VFP} + LBP + LCP\right)}{FMP} \qquad (5)$$

The number of buses needed outside the peak traffic period was estimated in the following manner: first, we estimated the round trip time and then divided this by the off-peak service frequency. Formally, the calculation is made as follows:

$$\frac{\left(\frac{2KR}{VFP} + LBFP + LCFP\right)}{FMFP} \qquad (6)$$

1.3 In addition to the number of buses needed, the total costs will depend on the total nomber of kilometres travelled, the total operating time of the buses, and the total time including both running time and rest periods. The time taken for a round trip at peak traffic time is given by:

$$\frac{KR}{VP} + \frac{2KR}{(VP + VFP)} \qquad (7)$$

to which we must add LBP + LCP to obtain the total round trip time including rest periods.

The total operating time and the total time including rest periods outside times of peak traffic density are calculated in accordance with the same principles.

The number of kilometres travelled by the buses is estimated by multiplying the total number of bus journeys by the distance travelled on each journey. The number of bus journeys to the centre outside the time of peak traffic density is obtained from:

$$\frac{HO - 2(t_1 - t_o)}{FMFP} \qquad (8)$$

The number of journeys made by the buses to the centre during the peak traffic periods is obtained from:

$$\frac{2(t_1 - t_o)}{FMP} \qquad (9)$$

The number of kilometres travelled by the buses is found by adding the results of formulas 8 and 9 and multiplying this by the round trip distance in kilometres.

1.4 It is considered that the total cost comprises: (i) the crew costs, which vary according to the number of hours of use of the buses, including rest periods; (ii) the time-dependent operating costs (which are different from the crew costs), estimated on the basis of the number of hours of use of the buses, excluding rest periods; (iii) the interest costs, which depend on the total number of buses in the fleet; and (iv) the operating costs which vary according to the number of kilometres travelled by the fleet. All these costs are calculated by simple arithmetical operations. Finally, the four cost components are added together to obtain the total daily cost.

1.5 The final product of the programme represent the total cost per passenger, which will indicate the fare to be charged. In calculating the number of passengers transported per day, we start from the basis that there are $(t_1 - t_o)$ hours of peak traffic density towards the centre in the morning and the same number in the evening. The maximum demand occurs in a single direction, for example when PPMP passengers per hour travel from the centre at the evening peak period, while only PPMFP passengers travel in the opposite direction.

1.6 The programme was conceived for calculating the cost per passenger. At all events, it stores the most important intermediate data for calculating this desired output.